Bangladesh Rice J. 20 (1) : 51-58, 2016

# Integrated Nutrient Management for Potato-Maize-T. Aman Rice Cropping Pattern

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## ABSTRACT

A field experiment on integrated nutrient management (INM) for Potato-Maize-T. Aman cropping pattern was conducted at BRRI RS farm, Rangpur (AEZ-3) during 2007-2010. The objectives were to examine the effect of Potato-Maize-T. Aman cropping on soil fertility and to develop appropriate fertilizer management practices for the above mentioned pattern. Inorganic and organic nutrient sources were tested in six different combinations in Rangpur region. Poultry manure (PM) @ 3.0 t $ha^{-1}$ + IPNS based inorganic fertilizers for potato ($N_{80}$, $P_0$, $K_{30}$, $S_0$, $Zn_0$, $Mg_4$, $B_1$) and maize ($N_{136}$, $P_0$, $K_{40}$, $S_2$, $Zn_{1.8}$, $Mg_2$, $B_1$) crops, and STB dose for T. Aman crop ($N_{65}$, $P_3$, $K_{27}$, $S_8$) has been recommended for Potato-Maize-T. Aman cropping pattern in Rangpur region. In fertilized plots, there was an apparent negative balance for N and K. The balances for P and S were positive. Organic C, total N and available P in soil increased due to integration of chemical fertilizer with PM. Results indicate that it is necessary to apply organic manure in combination with chemical fertilizer for sustaining soil fertility. For maize and potato crops, fertilizer dose needs to be updated after every three years of successive crop cultivation under Potato-Maize-T. Aman cropping pattern. Net additional income was the highest in $T_5$ where PM and IPNS based fertilizer applied.


**Key words:** Poultry manure, nutrient sources, soil health, nutrient balance

## INTRODUCTION

Maize is occupying third position among the cereals in Bangladesh and its acreage and production is increasing day by day from the base period. But three crops in a year Potato-Maize-Rice pattern uptakes a lot of nutrients from the soil. Gill and Singh (1978) found that fodder crop removed more K than either grain or cash crops. It was also found that combined application of organic and inorganic sources of nutrient to soils increased the use efficiencies of production inputs and also increased crop yields (Rahman, 2012; Rahman, 2013). Long-term basis poultry litter application and continuous cropping can increase soil carbon sequestration and labile carbon fractions, thereby offsetting atmospheric carbon dioxide emission and improving soil and environmental quality (Sainju *et al.*, 2008). Poultry manure has favourable effects on improving the soil moisture content and bulk densities of soil. According to Boateng *et al.* (2006) bulk density values were slightly lowered by the poultry manure. High moisture contents and lower bulk densities are better soil characteristics for good plant growth. In this context, this study was undertaken to find the effect of integrated nutrient management approach for Potato-Maize-T. Aman pattern in maintaining soil fertility and improving crop productivity as well to update fertilizer recommendation.

## MATERIALS AND METHODS

Field experiment was conducted at the BRRI RS farm, Rangpur (AEZ-3) during the period of Kharif-1, 2007 to Rabi, 2009-10. Table 1

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**Table 1. Initial soil characteristics of the experimental field.**

| Parameter | BRRI RS farm, Rangpur | |
|---|---|---|
| | 0-15 cm | 16-30 cm |
| pH (1:2.5) | 5.03 ± 0.13 | 5.30 ± 0.06 |
| Org. C (%) | 0.73 ± 0.02 | 0.57 ± 0.05 |
| Total N (%) | 0.07 ± 0.00 | 0.04 ± 0.00 |
| Available P (ppm) | 15.43 ± 0.89 | 7.03 ± 1.47 |
| Exchangeable K (meq/100 g soil) | 0.13 ± 0.02 | 0.10 ± 0.01 |
| Exchangeable Na (meq/100 g soil) | 0.27 ± 0.00 | 0.16 ± 0.10 |
| Available S (ppm) | 2.90 ± 0.20 | 2.70 ± 0.10 |
| Available Zn (ppm) (DTPA) | 1.10 ± 0.17 | - |

presents the initial soil characteristics of the experimental field. The soil texture of BRRI RS farm, Rangpur is sandy loam having strongly acidic reaction. Six treatment combinations were tested: $T_1$=Native nutrient; $T_2$=AEZ basis (BARC fert. Recom. Guide, 2005); $T_3$=Soil testbased (STB) dose; $T_4$=20% more than STB dose; $T_5$=Poultry Manure (PM) @ 3 t $ha^{-1}$ (oven dried) + IPNS basis inorganic fertilizer for maize and potato crop/$T_5$=same as $T_3$ for T. Aman crop and $T_6$=Farmers' practice (based on interview of 15/20 local farmers). Nutrient content of poultry litter is given as follows: moisture (33.6±4.77) %, OC (11.4±1.14) %, Total N (2.00±0.11) %, P (2.34±0.13) %, K (2.00±0.15) %, S (1.00±0.12) %, Zn (0.04±0.002) % and Mg (0.07±0.001) %. Table 2 presents detailed treatment description. The experiment was laid out in a randomized complete block design with three replications. The sources of N, P, K, S, Zn, B and Mg were urea, TSP, MoP, gypsum, zinc sulfate, borax and magnesium sulfate, respectively. Except urea, all other inorganic fertilizers were applied at final land preparation for all crops in the cropping pattern. Well decomposed PM was applied at final land preparation for maize and potato.

Urea was applied into three equal splits for maize and T. Aman crop: 1/3 N as basal, 1/3 N at 25-30 day after sowing (maize)/1/3 N at 15-20 DAT (T. Aman) and 1/3 N at 45-50 DAS (maize)/1/3 N at 27-30 DAT (T. Aman). For potato, urea was applied into two equal splits: ½ as basal and the rest ½ at 30-35 DAS. Necessary intercultural operations were done as and when ever required for each crop.

**Potato**

Potato (cv. Diamont/Granula) was tested. It was seeded on last week of November. One seed/pit (depth of 5.0-7.5 cm) was sown with line to line 50 cm spacing and seed to seed 20 cm apart.

**Maize**

Maize (BARI hybrid 3 (1st yr), BARI hybrid 2 (2nd yr) and BARI hybrid 5 (3rd yr), Kharif I) was grown at 2nd week of March of the conducted year. Two seeds/pit (at the depth of 2.5-5.0 cm) was sown with line to line 80 cm spacing and seed to seed 20 cm apart.

**T. Aman rice**

BRRI dhan33 was tested. Thirty- to thirty-five-day-old seedlings were transplanted using 2/3 seedlings/hill at 20 cm × 20 cm spacing on the 2nd and 3rd week of July of the conducted year.

At maturity, the maize and potato were harvested from the whole plot (Plot size: 4 m × 4 m) and T. Aman crop was harvested from 5 $m^2$ area at the centre of each plot. The grain yield of maize and T. Aman rice was adjusted to 14% moisture. The crop residue was recorded at oven dry basis. Economic analysis was done.

**Table 2. Treatment details for the Potato-Maize-T. Aman cropping pattern.**

| Treatment | Nutrient (kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|
| | N | P | K | S | Zn | Mg | B |
| | | | *Kharif-I (Maize)* | | | | |
| $T_1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $T_2$ | 196 | 36 | 75 | 30 | 3 | 3 | 1 |
| $T_3$ | 196 | 42 | 99 | 32 | 3 | 4 | 1 |
| $T_4$ | 235 | 50 | 119 | 38 | 3.6 | 5 | 1 |
| $T_5$ | 136 | 0 | 39 | 2 | 1.8 | 2 | 1 |
| $T_6$ | 95 | 15 | 30 | 10 | 0 | 0 | 0 |
| | | | *Kharif-II (T. Aman)* | | | | |
| $T_1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $T_2$ | 66 | 4 | 16 | 8 | 0 | 0 | 0 |
| $T_3$ | 65 | 3 | 27 | 8 | 0 | 0 | 0 |
| $T_4$ | 78 | 4 | 33 | 10 | 0 | 0 | 0 |
| $T_5$* | 65 | 3 | 27 | 8 | 0 | 0 | 0 |
| $T_6$ | 46 | 0 | 10 | 0 | 0 | 0 | 0 |
| | | | *Rabi (Potato)* | | | | |
| $T_1$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $T_2$ | 96 | 16 | 64 | 10 | 1.5 | 6 | 1 |
| $T_3$ | 139 | 11 | 91 | 10 | 1 | 6 | 1 |
| $T_4$ | 167 | 13 | 109 | 12 | 1 | 7 | 1 |
| $T_5$ | 79 | 0 | 31 | 0 | 0 | 4 | 1 |
| $T_6$ | 139 | 21 | 154 | 19 | 2 | 7 | 4 |

$T_1$ = Native nutrient, $T_2$ = AEZ basis (BARC fert. recom. guide, 2005), $T_3$= Soil test based (STB) dose, $T_4$ = 20% more than STB dose, $T_5$= PM @ 3 t ha$^{-1}$ (O D basis) + IPNS basis inorg. fertilizer, $T_5$* = Same as $T_3$ and $T_6$ = Farmers' practice.

Nutrient contents (N, P, K and S) from plant samples of the 1st and 2nd crop-cycle of the cropping pattern were determined by standard laboratory procedure (Yoshida *et al.*, 1972). After the completion of three crop-cycles, some physico-chemical properties of post harvest soil were studied following the standard procedure (Blake and Hartge, 1986; Black, C A, 1965; Jackson, M L, 1962; Page *et al.*, 1982). The recorded data were statistically analyzed using IRRISTAT version 4.1 (IRRI, 1998).

## RESULTS AND DISCUSSION

### Yield of potato

Table 3 presents the yield of potato in Potato- Maize-Rice pattern. Application of fertilizer significantly increased the tuber yield of potato and oven dried foliage yield. In 2007-80 the highest total fresh tuber yield (24.36 t ha$^{-1}$) was obtained with $T_5$ (Table 3). The significantly highest total biomass was obtained with $T_6$ (1.09 t ha$^{-1}$) followed by $T_5$ (1.08 t ha$^{-1}$). In 2008-09 treated plots $T_2$, $T_3$, $T_4$ and $T_5$ produced significantly identical total fresh tuber yield (17.41-19.57 t ha$^{-1}$) (Table 3). Significantly higher total biomass was obtained with $T_4$ (0.59 t ha$^{-1}$) followed by $T_5$ (0.55 t ha$^{-1}$).

In 2009-10 treatment $T_4$, $T_5$ and$T_6$ produced identical fresh tuber yield. The treatment $T_3$ reduced the fresh tuber yield than that of $T_4$. It indicates that $T_3$ (STB) is not quietly sound to produce tuber yield. After third year, it is needed to reformulate the STB dose after soil testing in case of potato. The treatment $T_5$ and $T_6$ produced identical bio-mass (Table 3).

**Table 3. Effect of integrated nutrient management on the yield of potato in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2010.**

| Treatment | Potato yield (t ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2007-08 (cv. Diamont) | | 2008-09 (cv. Diamont) | | 2009-10 (Granula) | | Mean | |
| | Tuber | Residue | Tuber | Residue | Tuber | Residue | Tuber | Residue |
| $T_1$ (Native nutrients) | 8.53 | 0.31 | 8.71 | 0.13 | 5.52 | 0.17 | 7.59 | 0.20 |
| $T_2$ (BARC Rec. Dose) | 19.01 | 0.62 | 17.41 | 0.37 | 17.06 | 0.30 | 17.83 | 0.43 |
| $T_3$ (STB) | 19.36 | 0.63 | 17.43 | 0.42 | 17.08 | 0.39 | 17.96 | 0.48 |
| $T_4$ (20% >STB) | 18.17 | 0.70 | 19.57 | 0.59 | 18.33 | 0.30 | 18.69 | 0.53 |
| $T_5$ (PM+IPNS) | 24.36 | 1.08 | 19.40 | 0.55 | 18.90 | 0.66 | 20.89 | 0.76 |
| $T_6$ (FP) | 20.37 | 1.09 | 16.60 | 0.52 | 19.13 | 0.65 | 18.70 | 0.75 |
| $LSD_{0.05}$ | 2.68 | 0.50 | 2.77 | 0.10 | 1.63 | 0.08 | - | - |
| CV (%) | 8.1 | 17.6 | 9.2 | 12.5 | 5.6 | 10.3 | - | - |

## Maize yield

Table 4 presents the yield of maize (BARI hybrid 3, 2 and 5) in Potato-Maize-Rice cropping *pattern. Applied fertilizer significantly increased the grain and straw yield of maize. In 2007, the highest grain yield of 6.67 t ha$^{-1}$ was obtained with $T_4$ followed by $T_2$, and these treatments were* statistically similar with other treated plots except $T_1$. All treated plots ($T_2$-$T_6$) produced statistically identical total biomass yield (9.59-12.71 t ha$^{-1}$).

In 2008, the highest grain yield of 6.29 t ha$^{-1}$ was obtained with $T_5$ followed by $T_4$, and these treatments were statistically identical. Treatment $T_2$, $T_3$ and $T_4$ produced statistically identical grain yield (5.31-5.75 t ha$^{-1}$). $T_1$ yielded the lowest yield (1.53 t ha$^{-1}$). The significantly highest straw yield (10.65 t ha$^{-1}$) was obtained with $T_5$ followed by $T_4$ and these treatments were statistically identical.

In 2009, the highest grain yield of 7.25 t ha$^{-1}$ was obtained with $T_4$ followed by $T_3$, and the treatments $T_3$, $T_4$ and $T_5$ were statistically identical. The highest straw yield of 10.71 t ha$^{-1}$ was obtained with the $T_5$.

## Yield of T. Aman rice

Table 5 presents the yield of T. Aman rice in Potato- Maize- Rice cropping pattern. Application of fertilizer significantly increased the grain and straw yield. In 2007, the significantly highest grain yield of 4.06 t ha$^{-1}$ was obtained with treatment ($T_4$) followed by $T_3$ (3.59 t ha$^{-1}$) (Table 5). The significantly highest straw yield of 4.57 t ha$^{-1}$ was obtained with $T_3$ followed by $T_4$ (4.12 t ha$^{-1}$).

In 2008, the significantly highest grain yield of 5.03 t ha$^{-1}$ was obtained with $T_5$ followed by $T_2$ (4.49 t ha$^{-1}$) (Table 5). The significantly highest straw yield of 4.27 t ha$^{-1}$ was obtained with $T_5$ followed by $T_3$ (3.79 t ha$^{-1}$).

**Table 4. Effect of integrated nutrient management on the yield of maize in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2009.**

| Treatment | Maize yield (t ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2007 (BARI hybrid 3) | | 2008 (BARI hybrid 2) | | 2009 (BARI hybrid 5) | | Mean | |
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| $T_1$ (Native nutrients) | 2.22 | 5.13 | 1.53 | 3.89 | 1.83 | 3.49 | 1.86 | 4.17 |
| $T_2$ (BARC Rec. Dose) | 6.28 | 10.27 | 5.31 | 7.98 | 5.65 | 7.28 | 5.75 | 8.51 |
| $T_3$ (STB) | 5.94 | 10.93 | 5.55 | 8.27 | 6.39 | 9.01 | 5.96 | 9.40 |
| $T_4$ (20% >STB) | 6.67 | 12.71 | 5.75 | 10.52 | 7.25 | 8.76 | 6.56 | 10.66 |
| $T_5$ (PM+IPNS) | 5.92 | 11.84 | 6.29 | 10.65 | 6.28 | 10.71 | 6.16 | 11.07 |
| $T_6$ (FP) | 4.13 | 9.59 | 4.64 | 7.78 | 5.27 | 8.80 | 4.68 | 8.72 |
| $LSD_{0.05}$ | 3.21 | 3.17 | 0.71 | 1.78 | 1.50 | 1.58 | - | - |
| CV (%) | 6.3 | 17.3 | 8.1 | 11.9 | 15.1 | 10.9 | - | - |

**Table 5. Effect of integrated nutrient management on the yield of T. Aman rice (BRRI dhan33) in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-09.**

| Treatment | Rice yield (t ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2007 | | 2008 | | 2009 | | Mean | |
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| $T_1$ (Native nutrients) | 2.44 | 2.35 | 2.82 | 2.37 | 2.06 | 1.58 | 2.44 | 2.10 |
| $T_2$ (BARC Rec. Dose) | 3.39 | 3.37 | 4.49 | 3.16 | 4.65 | 3.01 | 4.18 | 3.18 |
| $T_3$ (STB) | 3.59 | 4.57 | 4.42 | 3.79 | 4.69 | 3.05 | 4.23 | 3.80 |
| $T_4$ (20% >STB) | 4.06 | 4.12 | 4.27 | 3.25 | 4.59 | 3.00 | 4.31 | 3.46 |
| $T_5$ (PM+IPNS) | 3.54 | 3.98 | 5.03 | 4.27 | 5.33 | 3.13 | 4.63 | 3.79 |
| $T_6$ (FP) | 3.11 | 2.99 | 4.10 | 3.41 | 3.58 | 2.42 | 3.60 | 2.94 |
| $LSD_{0.05}$ | 0.51 | 0.65 | 0.59 | 0.61 | 0.71 | 0.78 | - | - |
| CV (%) | 8.4 | 10.1 | 7.7 | 10.0 | 9.5 | 16.0 | - | - |

In 2009, the significantly highest grain yield of 5.33 t ha$^{-1}$ was also obtained with the same treatment $T_5$ (PM+IPNS). It was similar to that of $T_2$ and $T_3$. But $T_4$ significantly reduced the grain yield than that of $T_5$. It indicates that $T_5$ (PM+IPNS) i.e. poultry manure adjusted with chemical fertilizer performed better. All treated plots ($T_2$-$T_6$) produced statistically identical straw yield (2.42-3.13 t ha$^{-1}$) (Table 5).

## Economic analysis

Table 6 presents the estimated total variable cost (TVC), gross return, total value of extra production (added return), net additional income and marginal benefit cost ratio (MBCR). Economic analysis was done considering the following: fertilizer cost, fertilizer application cost and labour cost for the additional product including by products due to fertilizer application.

The application of fertilizer increased the gross and added return and net additional income in all the treatments (Table 6). The gross return from the control plot (mean of 3 crop-cycles) was Tk 1,76,070/- and the application of fertilizer increased the gross return, which ranged from Tk 3,79,720/ha/ crop-cycle in $T_6$ to Tk 4,51,520/ha/crop-cycle in $T_5$. The highest added-return and net additional income (Tk ha$^{-1}$/crop-cycle) was obtained with $T_5$. The MBCR of all treated plots ranged from 5.43 ($T_5$) to 6.40 ($T_6$), which were higher than the permit able limit (2.00). Considering economic analysis and the soil health, it is appeared that the treatment $T_5$ (PM + IPNS) may be recommended.

**Table 6. Economic analysis of fertilizer management packages for Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur (mean of 3 crop-cycles).**

| Treatment | Grossretun** (Tk ha$^{-1}$/crop-cycle) | Total value of extra production (Tk ha$^{-1}$/crop-cycle) | TVC* (Tk ha$^{-1}$/ crop-cycle) | MBCR | Net additional income (Tk ha$^{-1}$/crop- cycle) |
|---|---|---|---|---|---|
| $T_1$ (Native nutrients) | 176070 | - | 0 | - | 0 |
| $T_2$ (BARC Rec. Dose) | 393675 | 217605 | 35058 | 6.21 | 182547 |
| $T_3$ (STB) | 401980 | 225910 | 38383 | 5.89 | 187527 |
| $T_4$ (20%>STB) | 421780 | 245710 | 44666 | 5.50 | 201044 |
| $T_5$ (PM+IPNS) | 451520 | 275450 | 50756 | 5.43 | 224694 |
| $T_6$ (FP) | 379720 | 203650 | 31802 | 6.40 | 171848 |

*Total variable cost (TVC) included fertilizer cost (chemical fertilizer and poultry manure), fertilizer application cost and labour cost for additional product. Price (Tk kg$^{-1}$): Urea=12; TSP=22; MP=15; Gypsum=5; $ZnSO_4$=100; $MgSO_4$=25; Borax=180 and PM=4. Labour wage rate = Tk.180/day. Two additional man-days/ha are required for applying fertilizer and four man-days/ha for per ton additional products including byproducts. **Price (Tk/kg): Rice grain=20; maize grain=12.50; potato=12; crop residue=2.

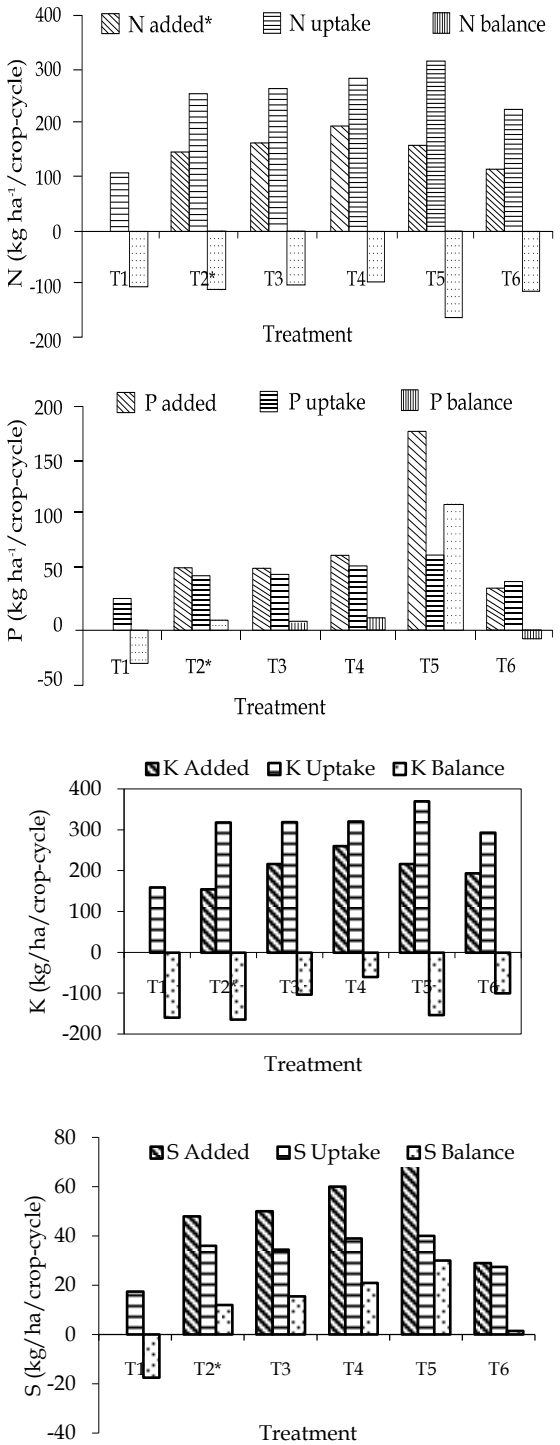


Fig. 1. An apparent nutrient balance sheet in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2009 (Mean of 2 crop-cycles).

**Apparent nutrient balance**

An apparent nutrient balance was calculated as the difference between the amounts of nutrient added through fertilizers and manures and the amount of nutrients removed by crop annually (Maize + T. Aman + Potato). It was observed that the apparent nutrient balance in the control plot was always negative for all the nutrients since no fertilizer or manure was added to the plot. In the fertilized plots there was an apparent negative balance for N and K. The balances for P and S were positive as expected, a good amount of P and S were accumulated in the fertilized plot, which indeed, had residual effect on the following crops and also for applied poultry litter (Fig. 1).

**Changes of chemical properties**

After the completion of three crop-cycles, some physico-chemical properties of post harvest soil were studied. Table 7 shows that the mean bulk density ranged from 1.28 to 1.55 gm $cm^{-3}$ among the treated plots at different soil depths. Organic C, total N, available P increased due to integration of chemical fertilizer with poultry manure (Table 8). Manure application has been reported to increase soil P concentrations of both total and soluble P, as well as concentrations of specific P forms, including stable organic P moieties (Waldrip-Dail *et al*. 2009). The available status of Seven in control plot was increased from initial value. This increase might be due to the industrial urbanization. Whereas, the exchangeable K decreased from the initial soil value because of luxurious consumption by the crops and nutrient mining.

**Table 7. Effect of integrated nutrient management on the soil bulk density in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-10.**

| Treatment | Soil depth, cm | BRRI, Rangpur | | |
|---|---|---|---|---|
| | | Bulk density (g/cm3) | | |
| | | R-I | R-II | Mean |
| $T_1$ (Native nutrients) | 0-15 | 1.40 | 1.50 | 1.45 |
| | 16-30 | 1.21 | 1.35 | 1.28 |
| $T_3$ (STB) | 0-15 | 1.57 | 1.53 | 1.55 |
| | 16-30 | 1.55 | 1.41 | 1.48 |
| $T_5$ (PM+IPNS) | 0-15 | 1.47 | 1.55 | 1.51 |
| | 16-30 | 1.43 | 1.37 | 1.40 |

**Table 8. Effect of integrated nutrient management on the chemical properties of post harvest soilin Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2009-10.**

| Treatment | pH | Org. C (%) | Total N (%) | Available P (ppm) | Exch. K (meq/100 g soil) | Available S (ppm) |
|---|---|---|---|---|---|---|
| | | | 0-15 cm | | | |
| $T_1$ | 5.97 | 0.78 | 0.08 | 6.67 | 0.11 | 6.00 |
| $T_2$ | 5.39 | 0.57 | 0.06 | 21.67 | 0.15 | 10.33 |
| $T_3$ | 5.80 | 0.50 | 0.05 | 25.33 | 0.10 | 10.00 |
| $T_4$ | 5.87 | 0.43 | 0.04 | 31.33 | 0.08 | 12.00 |
| $T_5$ | 6.10 | 0.77 | 0.08 | 46.00 | 0.12 | 8.33 |
| $T_6$ | 5.88 | 0.31 | 0.03 | 13.00 | 0.10 | 9.67 |
| $LSD_{0.05}$ | 0.41 | 0.15 | 0.02 | 3.47 | 0.03 | 1.90 |
| CV(%) | 3.80 | 15.1 | 15.1 | 7.90 | 12.4 | 11.10 |
| Initial soil | 5.03 | 0.73 | 0.07 | 15.43 | 0.13 | 2.90 |
| | | | 16-30 cm | | | |
| $T_1$ | 5.98 | 0.50 | 0.05 | 3.00 | 0.08 | 11.00 |
| $T_2$ | 5.74 | 0.49 | 0.05 | 4.67 | 0.10 | 13.00 |
| $T_3$ | 5.92 | 0.49 | 0.05 | 3.00 | 0.11 | 12.33 |
| $T_4$ | 6.03 | 0.40 | 0.04 | 2.67 | 0.09 | 11.00 |
| $T_5$ | 6.34 | 0.56 | 0.06 | 4.00 | 0.11 | 10.67 |
| $T_6$ | 6.13 | 0.36 | 0.04 | 3.33 | 0.11 | 10.00 |
| $LSD_{0.05}$ | NS | 0.11 | 0.01 | NS | NS | NS |
| CV(%) | 3.50 | 12.50 | 12.50 | 34.20 | 14.00 | 16.50 |
| Initial soil | 5.30 | 0.57 | 0.04 | 7.03 | 0.10 | 2.70 |

## CONCLUSIONS

PM @ 3.0 t $ha^{-1}$ + IPNS based inorganic fertilizers for potato and maize crops, and STB dose for T. Aman crop may be a good fertilizer management package for Potato-Maize-T. Aman cropping pattern. To sustain soil fertility, it is necessary to apply organic manure in combination with chemical fertilizer. For maize and potato crops, fertilizer recommendation should be updated alternate in every three years.

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